

## **PHASING**

The simplest and most common type of phasing is two-phase operation, with a phase for main line traffic and another phase for the cross street. In this two-phase sequence, the major crossing through movements are separated, but the left-turn movements must yield to opposing traffic, turning only when there is an adequate gap in the opposing traffic. The next most commonly added phasing is for left turns and then pedestrians.

More intersectional problems are caused by left-turning traffic than any other vehicular movement. The identification of such a problem may be obtained through accident analysis or capacity analysis. The selection of any combination of lane assignments or signal treatments should be based upon the overall effectiveness of the control schemes available. These problems can be treated in a number of ways. The objectives of any treatment, are either an increase in capacity, a decrease in accident potential, or a combination of the two.

### **Left Turn**

The following outlines the basic sequences used to accommodate left-turn movements:

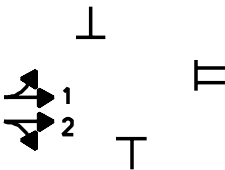
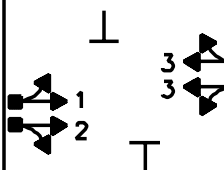

#### **Advance Green (Protected/Permitted)**

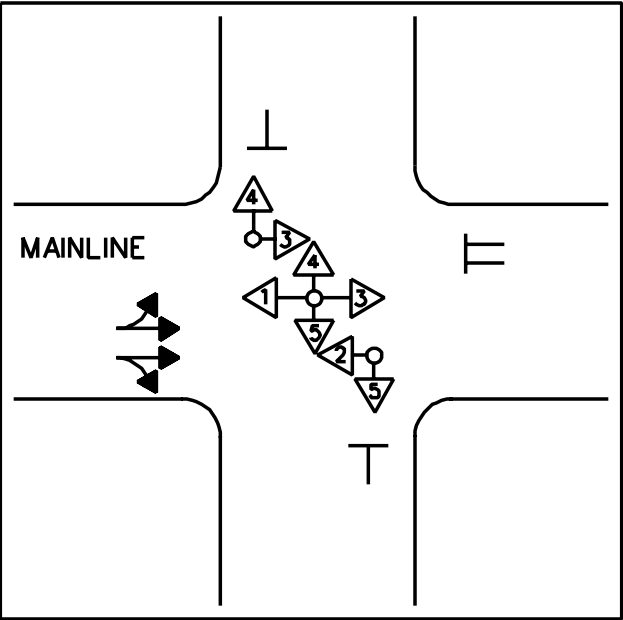
This is a sequence in which the left-turning vehicles from only one approach first are allowed to move together with the through traffic on that approach while the opposing traffic is stopped and then also permitted to move on the arterial phase which follows.

The protected left-turn portion of the phase is terminated through the display of a yellow arrow and a circular green simultaneously. The advance can be either fixed time or actuated.

This type of phasing can be used preferably with the provision of an exclusive left-turn lane, but may also be used without an exclusive left turn lane.

The signal indication displays to be used with this type of phasing are shown on the following page.

NONE														
		PHASE 1			PHASE 2			PHASE 3			PHASE 4			
NTOR		FLASH	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL
F A C E #	1	Y	G←	G←Y	G	G	Y	R				R	R	R
	2	Y	G	G	G	G	Y	R				R	R	R
	3	Y	R	R	R	G	Y	R				R	R	R
	4	R	R	R	R	R	R	R				G	Y	R
	5	R	R	R	R	R	R	R				G	Y	R



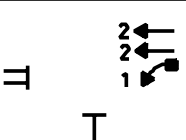
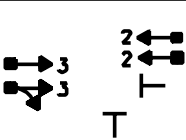
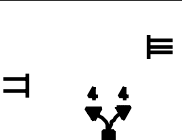
#### Required Conditions Mainline

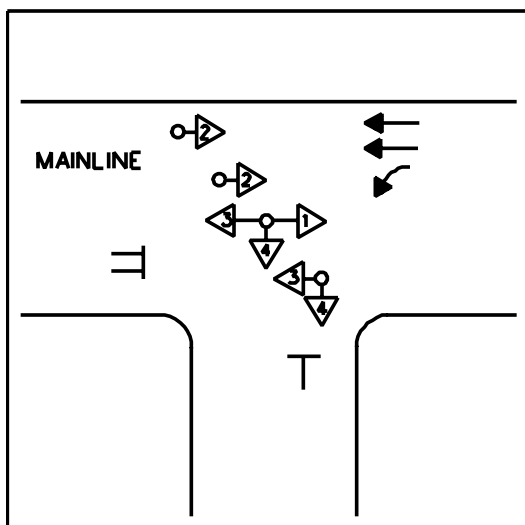
1. Single or multi-lane approach preferably with, but also without a separate left turn lane.
2. Two faces per approach.

This is a sequence in which the left-turning vehicles from only one approach are allowed to move together with the through traffic on that approach, but then not permitted to move on the arterial phase which follows.

To implement this type of phasing an exclusive left-turn lane is required. An exclusive left-turn signal is provided to control this left-turn movement and the protected advance is terminated by the display of a yellow arrow followed by a circular red on the left-turn signal. The advance can be fixed time or actuated.

The signal indication displays to be used with this type of phasing are shown in the following.

NONE															
		T				T									
NTOR		PHASE 1				PHASE 2				PHASE 3			PHASE 4		
F A C E #	FLASH	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL		
	1	R	←	←Y	R	R	R	R				R	R	R	
	2	Y	G	G	G	G	Y	R				R	R	R	
	3	Y	R	R	R	G	Y	R				R	R	R	
	4	R	R	R	R	R	R	R				G	Y	R	



#### Required Conditions Mainline

1. Two or more lane approach with a separate left turn lane.
2. Two faces per approach for through traffic.
3. Separate left turn signal for advancing left turn movement into side street.

This is a sequence in which left turns in one direction are allowed to move protected from opposing through traffic following the arterial phase.

Permitted/protected lag green phasing does not require an exclusive left-turn lane to implement. A permitted/protected lag green is terminated with the display of a circular yellow followed by a circular red, which is the display given to through traffic on the same approach as the lag. For a protected only lag, an exclusive left-turn lane and indication is required and termination of the lag is accomplished by the display of a yellow arrow followed by a circular red. Discretion should be used with lag-left turn phasing as it can introduce operational problems, which should be recognized and avoided during the design and implementation process. By far the most critical of these problems is where one approach's right-of-way is terminated while the opposing approach continues.

Ordinarily, the left-turning driver facing a yellow display will expect the opposing through traffic to also have a yellow signal and that the through traffic will be stopping. Therefore the driver believes that the turn can be completed on the yellow indication or immediately after. Since through traffic is not stopping, a potentially undesirable condition exists. A span-mounted sign "Opposing Traffic Has Longer Green" may be installed. The potential conflict does not occur at "T" intersections and at diamond interchanges.

In spite of the potential conflict, there are some advantages associated with lag-left phasing:

- Both directions of straight through traffic start at the same time.
- Approximates the normal driving behavior of vehicle operators with the execution of the left turn movement in gaps at the end of the through movement phase for the lag direction.
- Provides for vehicle/pedestrian separation as pedestrians normally cross at the beginning of the straight through green interval. Where pedestrians are crossing the side street concurrently, the pedestrian clearance has been completed prior to the beginning of the lagging-green interval.
- Left turns do not pre-empt the right-of-way from the opposing straight through traffic movement and takes advantage of increased headway after the initial queue passes.
- If the signal is coordinated for through traffic it is also coordinated for left-turn traffic. Coordinated systems with all leading lefts may have a tendency for traffic to arrive at the left-turn signal just as it turns yellow.

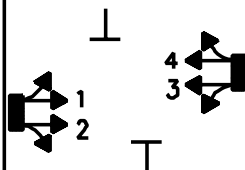
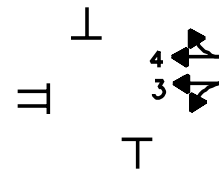
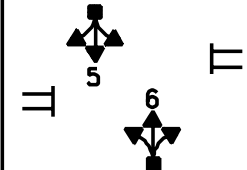
- Cuts off only the platoon stragglers from adjacent signalized interconnected intersections.

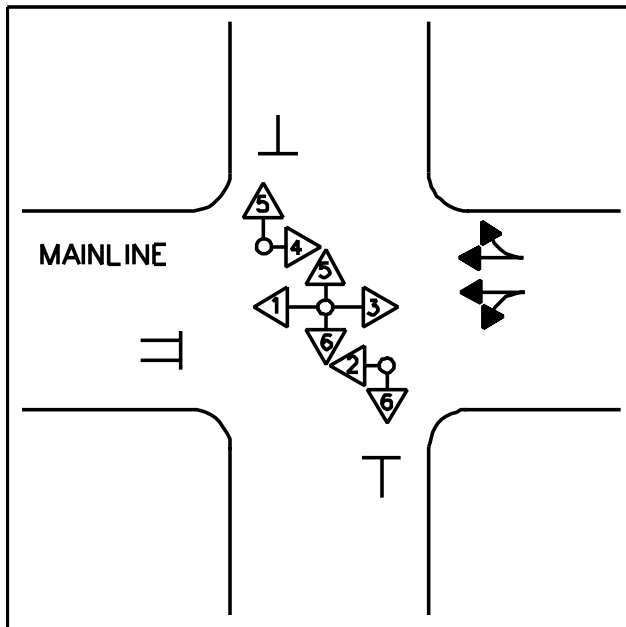
Lagging left turns normally will not be used if oncoming traffic has any one of the following types of left-turn treatments: permitted, leading protected and permitted, or lagging permitted and protected with a different split for the opposing left turn.

This restriction tends to limit the use of lagging left-turn phasing to a few specific situations when oncoming traffic has the following left-turn treatments: protected leading, protected lagging (if the oncoming left split is less than or equal to this left's split), prohibited (at a T intersection or if a cross street is one-way in) or; with split phasing.

The signal indication displays to be used with this type of phasing are shown on the following pages.

Log Green (Permitted/Protected)

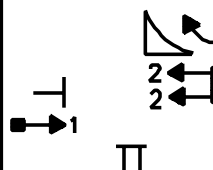
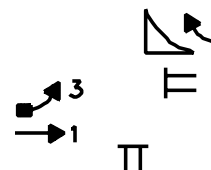
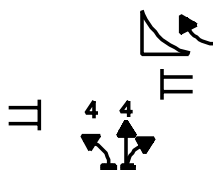
NONE														
														
NTOR			PHASE 1			PHASE 2			PHASE 3			PHASE 4		
	FLASH	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	
F A C E #	1	Y				G	Y	R	R	R	R	R	R	
	2	Y				G	Y	R	R	R	R	R	R	
	3	Y				G	G	G	G ←	Y	R	R	R	
	4	Y				G	G	G	G	Y	R	R	R	
	5	R				R	R	R	R	R	R	G	Y	
	6	R				R	R	R	R	R	R	G	Y	

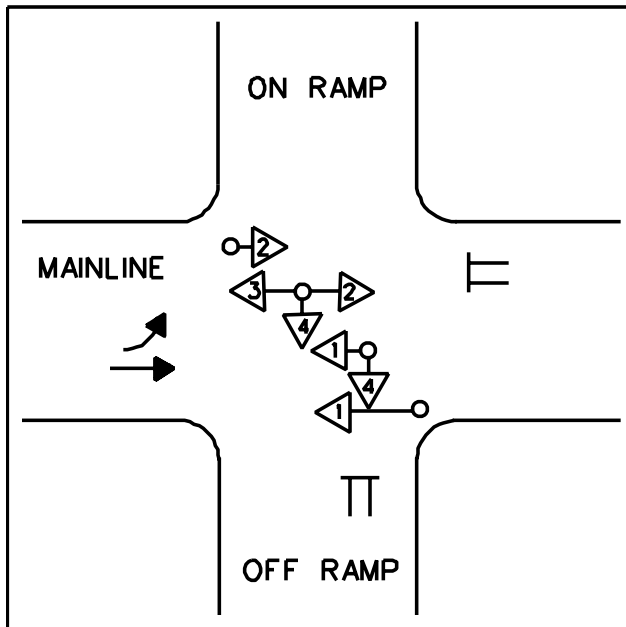


Required Conditions Mainline

1. Single or multi-lane approach with or without a separate left turn lane.
2. Two faces per approach.

# Protected Left Turn Phase (Lagging)

NONE														
														
NTOR		PHASE 1			PHASE 2			PHASE 3			PHASE 4			
		FLASH	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL
F A C E #	1	Y				G	G	G	G	Y	R	R	R	R
	2	Y				G	Y	R	R	R	R	R	R	R
	3	R				R	R	R	←	←Y	R	R	R	R
	4	R				R	R	R	R	R	R	G	Y	R



## Required Conditions Mainline

1. 2 or more lane approach with a separate left turn lane.
2. Two faces per approach for through traffic.
3. Separate left turn signal for lagging left turn movement into side street.

## Lead - Lag

This phasing is combined with a leading protected left in one direction, followed by the through movements, followed by a lag left in the opposing direction. It is sometimes used in systems to provide a wider two-way through band.

Lead-Lag (protected/permitted)

NONE														
		PHASE 1			PHASE 2			PHASE 3			PHASE 4			
NTOR		FLASH	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL
F A C E #	1	Y	G←	G←Y	G	G	Y	R	R	R	R	R	R	R
	2	Y	G	G	G	G	Y	R	R	R	R	R	R	R
	3	Y	R	R	R	G	G	G	G←	Y	R	R	R	R
	4	Y	R	R	R	G	G	G	G	Y	R	R	R	R
	5	R	R	R	R	R	R	R	R	R	R	G	Y	R
	6	R	R	R	R	R	R	R	R	R	R	G	Y	R

Lead-Lag (protected Only)

NONE															
			PHASE 1			PHASE 2			PHASE 3			PHASE 4			
NTOR			FLASH	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL
F A C E #	1	R	←	←Y	R	R	R	R	R	R	R	R	R	R	R
	2	Y	R	R	R	G	G	G	G	Y	R	R	R	R	R
	3	R	R	R	R	R	R	R	R	R	R	G	Y	R	R
	4	R	R	R	R	R	R	R	R	R	R	G	Y	R	R
	5	R	R	R	R	R	R	R	←	←Y	R	R	R	R	R
	6	Y	G	G	G	G	Y	R	R	R	R	R	R	R	R



This is a sequence in which opposing left turns move simultaneously followed by the through movements. If the left turns follow the through movements, it is call a "**lag dual left**." In this type phasing, left turns can be made as protected movements solely or permitted to additionally move with the through traffic. Generally this type of left-turn phasing is most effective when opposing left turns are approximately equal. Reference should be made to the preceding sections for the appropriate signal indication displays and signal face requirements.

## Directional Separation

It has become necessary at times to separate side street phases at certain offset side streets or where heavy left turns are encountered, moving all traffic on one side street, then totally stopping that traffic and letting the other side street move on an exclusive, protected phase. When this type of phasing is selected, a circular green with left-turn arrow is to be displayed on the left most signal face.

## Quad

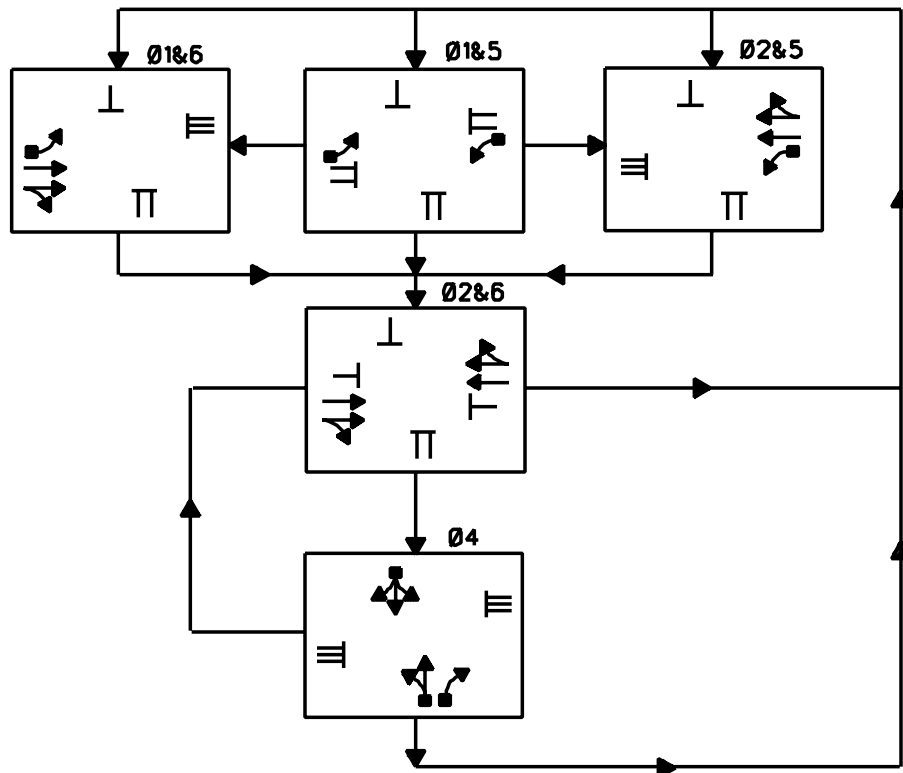
In this operation each vehicle movement operates as a separate phase which times concurrently but independently with other non-conflicting phases. Opposing left turns start simultaneously as a dual advance. When demand is met in one direction, termination of that left turn occurs and the through movement starts in the opposite direction in which left turn demand still remains. When the remaining left turn is satisfied, termination occurs and the through movement in the direction of the lighter volume left turn starts. This phasing is effective where the left turn volumes at times vary considerably. The signal indication displays to be used with this type of phasing are shown on the following pages.

For additional information on left-turn treatments refer to NCHRP Synthesis 225 - Left Turn Treatments at Intersections, reference number 7.

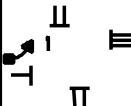
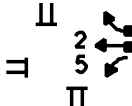
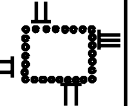
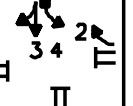
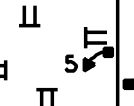
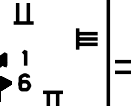
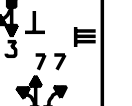
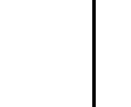

Quad (Protected)

[illegible]

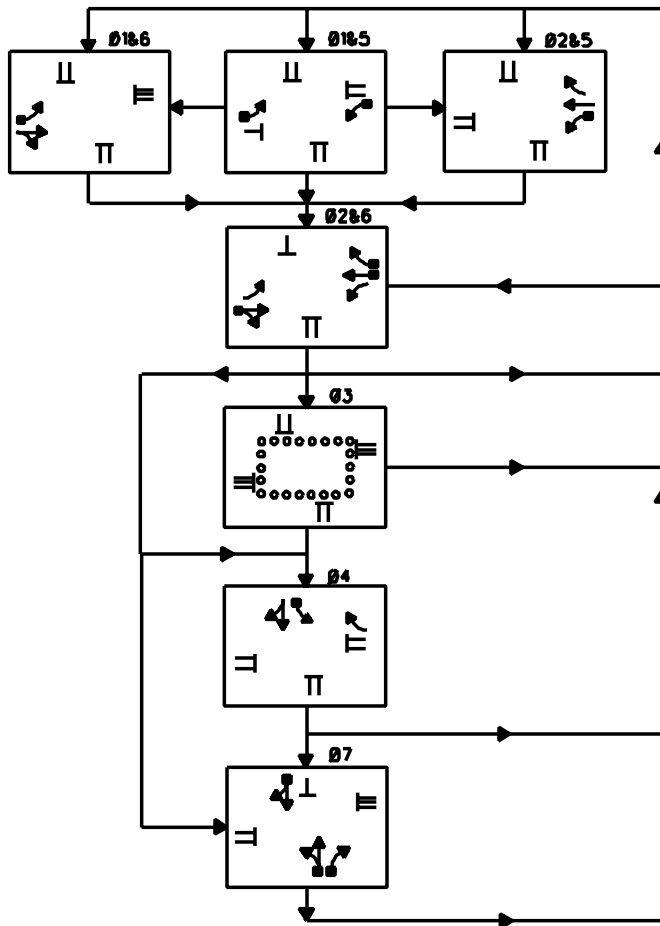
The phasing diagram shown below is placed on the bottom half of signal plans to clarify the sequence of phasing associated with this type of operation.



# Quad (Protected/Permitted)

NONE		MOVEMENT DIAGRAM																															
																																	
NTOR		PHASE 1				PHASE 2				PHASE 3				PHASE 4				PHASE 5				PHASE 6				PHASE 7				PHASE 8			
	FLASH	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL	GRN	CL	CL		
F A C E #	1	Y	←R	←YR	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	G	Y	R	R	R	R	R	R	R	R	R	R		
	2	Y	R	R	R	G	Y	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R		
	3	R	R	R	R	R	R	R	R	R	R	R	R	G	G	G	R	R	R	R	R	R	R	G	Y	R	R	R	R	R			
	4	R	R	R	R	R	R	R	R	R	R	R	R	←	←Y	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R		
	5	Y	R	R	R	G	Y	R	R	R	R	R	R	R	R	R	R	←R	←YR	R	R	R	R	R	R	R	R	R	R	R	R		
	6	Y	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	G	Y	R	R	R	R	R	R	R	R	R	R	
	7	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R	G	Y	R	R	R	R	R	R		
	P	OFF	←	←	DW	←	←	←	←	←	←	←	←	←	←	←	←	DW	←	←	←	←	←	←	←	←	←	←	←	←	←		

The phasing diagram shown below is placed on the bottom half of signal plans to clarify the sequence of phasing associated with this type of operation.



## TECHNICAL NOTES

① TO BE R → IF PHASE 2 NEXT.

PHASES 1&5 TO DRIVE FACES 1&5

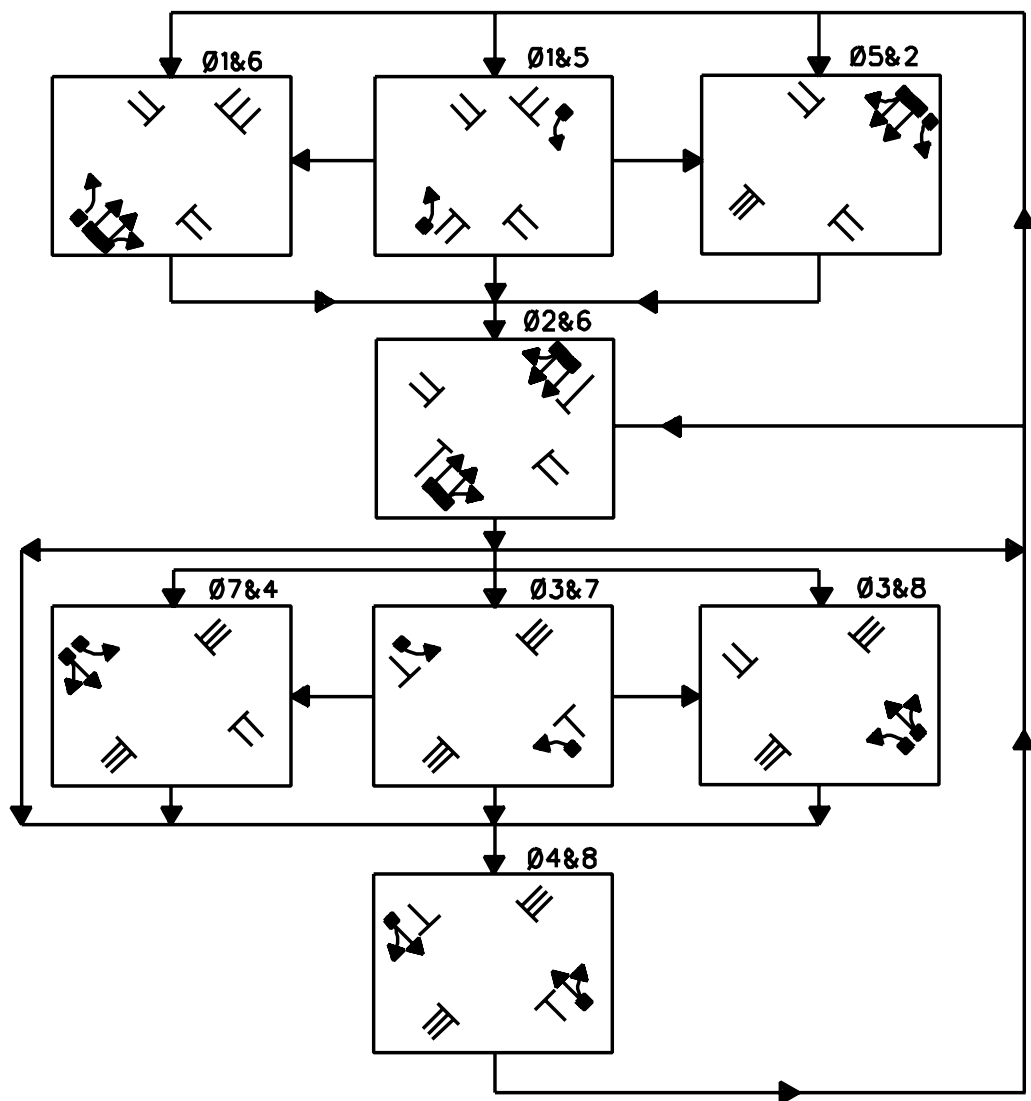
←Y AND ← ONLY

PHASE 2&6 TO DRIVE FACES 1&5 R,Y&G

The right turn overlap is a non-standard overlap and requires special notes.

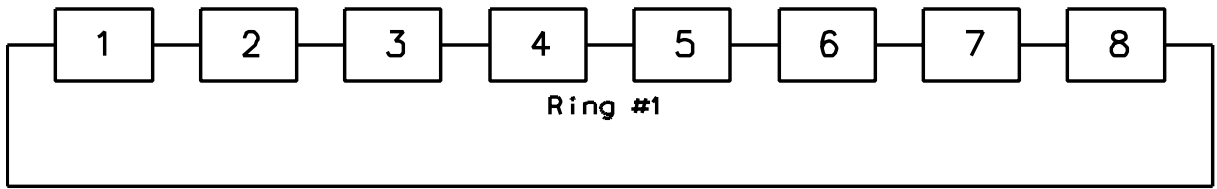
Typical Phase Sequence Flow Chart  
Dual Ring Application

PHASE 1	PHASE 2	PHASE 3	PHASE 4	PHASE 5	PHASE 6	PHASE 7	PHASE 8



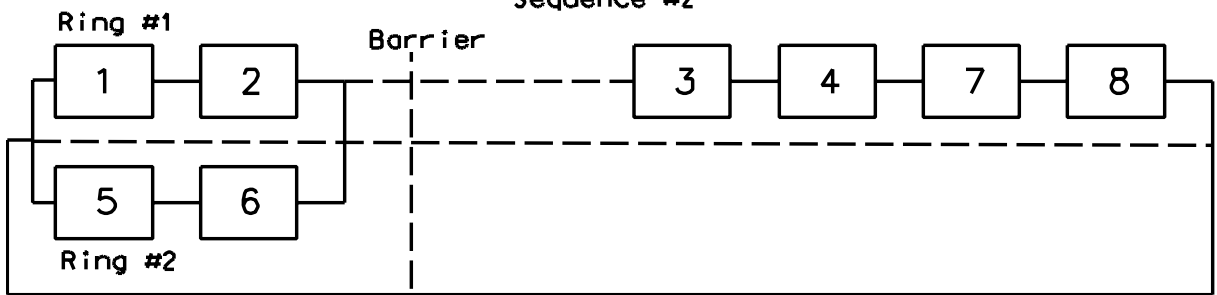
# Required Sequences of Operation

Sequence #1



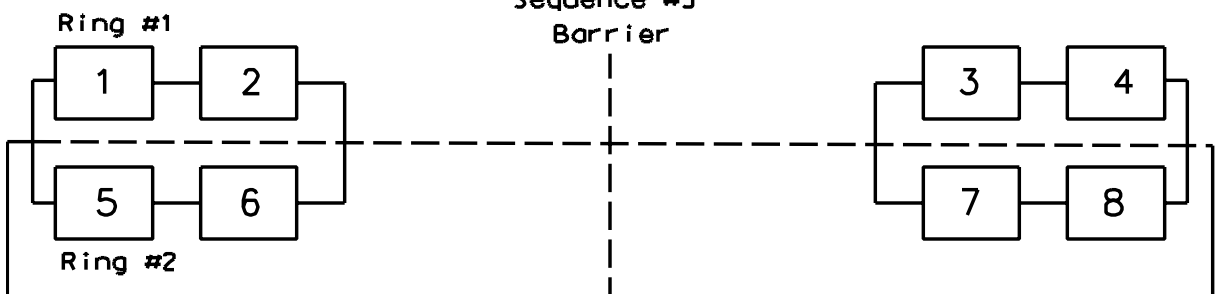
Single Ring Operation

Sequence #2



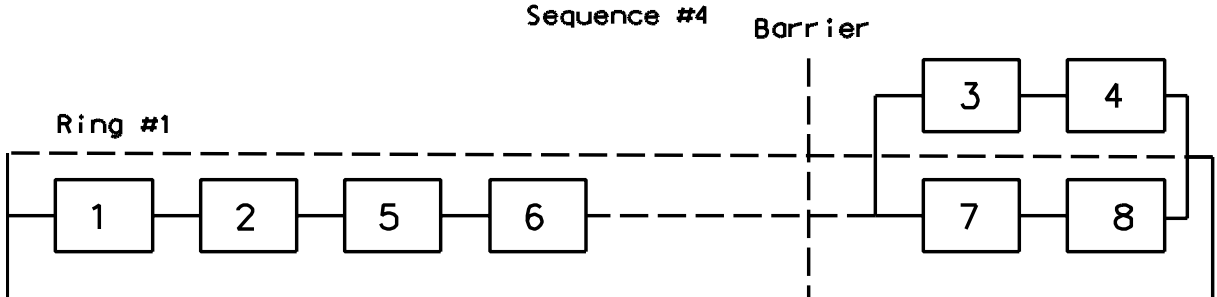
Dual Ring Operation

Sequence #3



Quad Left Turn, Dual Ring Operation

Sequence #4



Dual Ring Operation

## Turn Overlap

Turn Overlap is a phasing operation in which the left-turn movement from one street moves concurrently with the right-turn movement from the intersecting street. Most commonly, this involves left turns from the artery and right-turns from the side street.

Turn overlaps should be used only when necessary. The benefits of an overlap are to be compared to potential conflicts with pedestrians in the vicinity of the intersection and potential conflicts with other vehicles in the intersection area as well as downstream. There should be a significant volume on the artery making a left turn and on the side street making a right turn. Moving the right-turn volume in the overlap phase should reduce the green time needed for the side street.

The intersection geometry must be conducive to allow the overlap feature. Separate turn lanes of adequate length, appropriate corner radii and proper lane width should be provided. Right turn on red can accommodate significant right turning volumes without providing the special overlap phase.

The placement and use of detectors for this type of operation deserves careful consideration:

- Detectors for the left or right turn may not be necessary. If no detector is provided then the feature will be provided every cycle and the timing will not be responsive to volume changes. This may be desirable if the signal is in a system and the turn movements are considered the major traffic flow and the signal rests in the overlap phase.
- Detectors for the overlap phase can be provided for the left-turn lane only. The overlap phase would then provide side street right turns extra time to move and accommodate the side street right turning traffic that was not handled by the side street phase.
- Detection for the overlap phase can be provided on the left-turn lane and right-turn lane. However, the phase could be unnecessarily extended if heavy left-turn and right-turn queues approach the signal at different periods during the overlap phase.
- The artery left turn and the side street right turn can be provided with separate phases and separate detection. The side street right turn can be overlapped with the artery left turn or the side street through movement. Since the right turn would have a separate phase and timing, the signal could be made more responsive to traffic demand.